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Upper Paleolithic Notation and Symbol

Sequential microscopic analyses of Magdalenian engravings document possible cognitive origins of writing.

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Microscopic analyses of a large proportion of the engraved compositions on stone and bone excavated during the last hundred years from Upper Paleolithic levels in Europe (*1*) have provided a new body of data; this has necessitated a substantial revision of concepts concerning the symbolic and cognitive complexities of the first widely dispersed *Homo sapiens sapiens* cultures, circa 34,000 to 10,000 B.C. The data have revealed an unexpected tradition, not merely of making images and compositions but of periodic, repetitive use and accumulation of certain classes of images and symbols. These indicate some of the probable origins of later formal systems, such as writing, arithmetic, and true calendrics, which emerge soon after the Upper Paleolithic.

The microscopic analyses conducted during the last 7 years document at least a dozen classes of symbol and symbol usage, each with its own semantic content and specialized function, in the Upper Paleolithic of Europe. The separate development of these diverse systems, representing the first art and symbol of modern man, can be tracked through the full 25,000-year period of the Upper Paleolithic and into the Mesolithic period that followed, circa 8000 to 5000 B.C. (*2–7*). Aspects of these prehistoric traditions appear later in the Neolithic cultures of Europe after agriculture had been adopted.

This article presents the analysis of one late Upper Paleolithic bone tool which also served as a surface for the accumulation of a complex notation and the periodic use of engraved animal images. The traditions of notation and animal imagery began in the Aurignacian, c. 32,000 B.C., among the early Cro-Magnon hunters (*4–6*), but the notations and images in this period are usually found on separate artifacts or marking surfaces. During the Middle Magdalenian, c. 15,000 to 13,000 B.C., there began to appear in France and Spain engraved compositions on bone and antler in which recognizable images (animal, plant, human) and abstract signs are intentionally associated with sequential sets of unit marks. Notations of this type are known ethnographically and historically in the Old and New Worlds (*8–11*), but they have not before been documented for the Upper Paleolithic.

Analysis of these Magdalenian associations has made it possible to begin the study of the relation among these classes of symbols and to assay some of the contents in their use and association. This article begins the publication of these analyses and interpretations (*12*).

La Marche: Middle Magdalenian

At the site of La Marche in central France between 1937 and 1938 a few hundred engraved and carved bone and stone artifacts were excavated from Magdalenian III levels, c. 13,000 B.C. These include decorated tools, pendants, amulets, engraved batons, and a library of engraved stones containing the images of animals and humans (*13*). The human images are unusual in their variety, depicting naked, perhaps pregnant women, costumed men in seemingly ritual stance, coiffured female heads, bearded oldsters, and adolescents. The sum of these engraved mobiliary materials indicates an exceedingly rich iconographic, symbolic usage.

Visually the least interesting piece from La Marche comes from a slightly later but closely related level (Magdalenian IV). It is a discolored, deteriorated fragment of bone, 21 centimeters long, engraved with a faint series of marks and lines (Fig. 1, a to c). It is on display, without description, among other fragments at the Musée de l'Homme, Paris. The excavator, S. Lwoff, described the bone as a fragment containing engraved horses and "ponctuations" but made no other comment (*14*). Microscopic examinations conducted over a 3-year period (*15*) revealed an unforeseen cognitive complexity, which became increasingly apparent as the analysis proceeded.

The first examination showed that the main face had been engraved with rows of tiny marks which were formed into "blocks" or sets of marks, each set engraved by a different point. The three rows in mid-bone (Fig. 2, a to c) are engraved by a point or cutting edge that flares near the top of the bite, creating a relatively wide, irregular angle in the cross section (⌃), and by a turning or twisting stroke that forms a partial arc: ↻. The rows in this central set are separated by a wide

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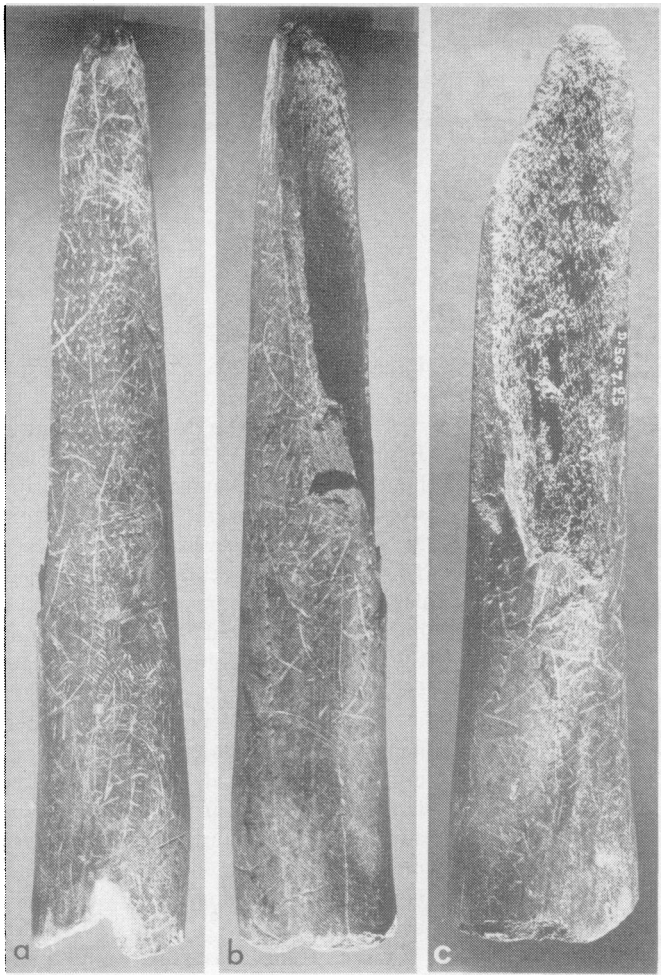

Fig. 1. (a to c) Three sides of a bone fragment from La Marche, France, c. 12,000 B.C., indicating the faint engraved markings, the general discoloration and deterioration of the surface, and the section that was broken away from the rear (21 cm).

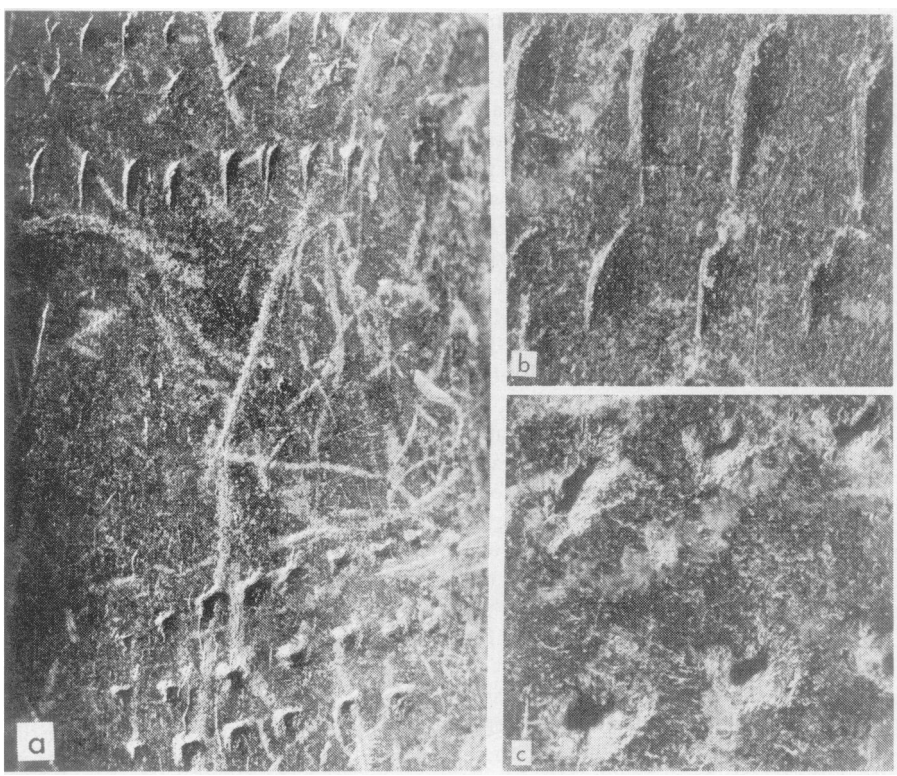

Fig. 2. (a) Detail of the central portion of Fig. 1a, documenting two separated sets of tiny marks (G^{1-5}, H^{1-5}), each set engraved by a different point and type of stroke. (b and c) Close-ups of marks in each set ($G^{1,2}$, $H^{1,2}$), indicating the different imprint or cross section for each set and the differences in the type of stroke and the direction of engraving.

space from the sets above and are engraved at an angle of 15° to the base line of the sets above, which suggests that the bone had been held at a different angle to the vertical. The rows in the set above are perpendicular to the vertical axis of the bone, and each mark is engraved with a sharp, straight-sided point (V) and by use of a single downward stroke: ↓. The cutting edge that engraved one set could not have engraved the other. The examination also revealed that the horse below the marks in mid-bone had been engraved by still a third point, cutting a narrower, finer cross section (Y).

The tradition of accumulating marks with changes in the engraving point, the style of stroke, and the angle and pressure of engraving, and with a spatial separation of sets, had been documented earlier for the Upper Paleolithic (*4, 5*). These data had suggested that such sets were neither random nor decorative but had been intentionally accumulated over a period. Since the preliminary examination of the La Marche bone indicated engraving in this tradition, microscopy was applied to all the engraved marks on both faces. The results of the analysis were then applied to engraved examples in other collections in Europe, the comparative results were brought back, and the La Marche bone was examined again. The final analytic results of a process that continued for years are presented here sequentially, beginning with the marks along the break in the bone on the reverse face (Fig. 1b).

The break had cut longitudinally through at least 14 rows of marks (coded J to Q); five rows that were intact below the jagged separation (R^{1-5}) indicated that the missing sets had been accumulated horizontally like those on the other face (Fig. 3a). Microscopic examination showed that these broken sets had been engraved by many points, different from those which engraved the two sets I had examined on the prior face. These marks had been made to different lengths, by different pressures, and in different directions. The point of impact, the direction of the stroke, and the tailing out revealed that some sets had been engraved downward (/) and others in reverse (/), indicating that the bone had been turned 180° to engrave closely adjacent sets (Fig. 3, b and c). The angle and direction of the engraving showed that each stroke had been made by a tool held in the right hand, engraving to the left and downward

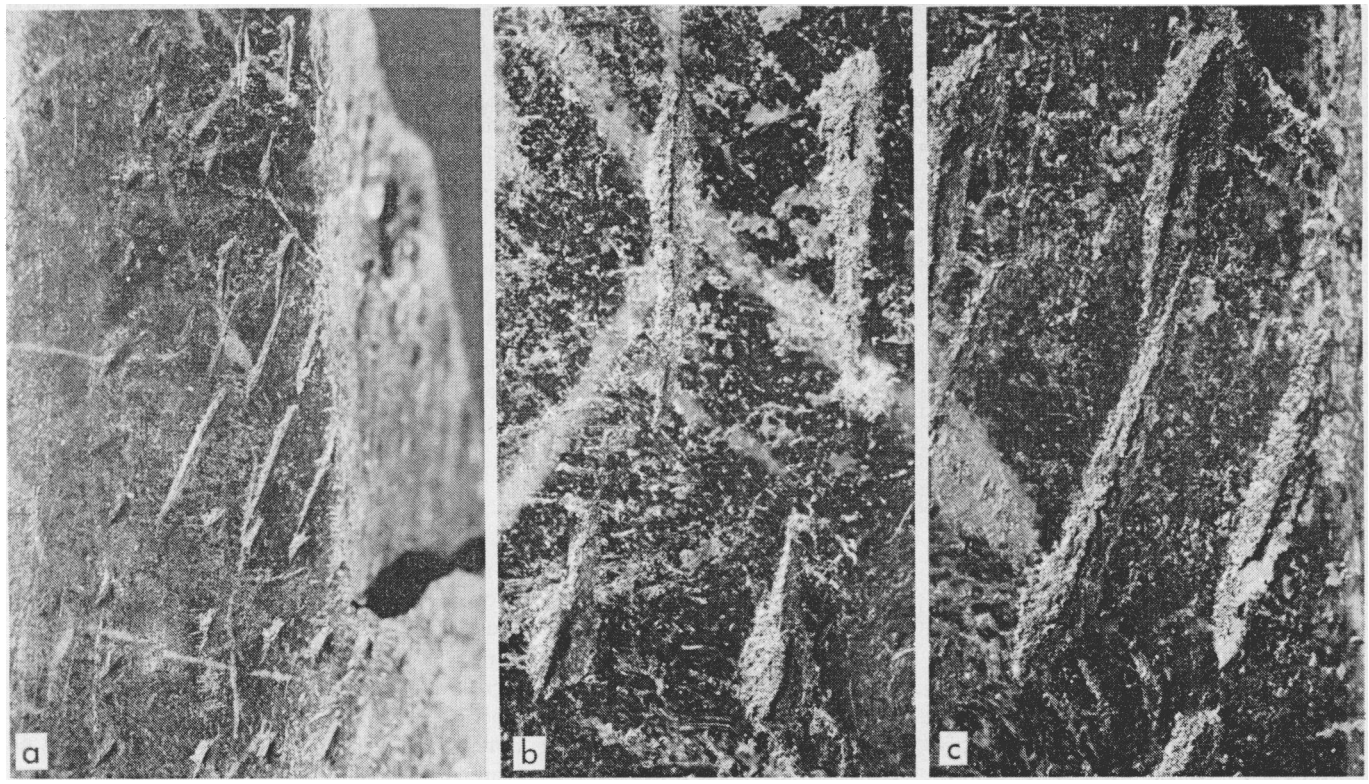

Fig. 3. (a) Detail of the central portion of Fig. 1b, indicating the row of marks along the vertical break. Different rows are engraved in reverse directions and by different pressures and rhythms. At the left is a row of marks accumulated vertically and engraved by a different point. (b and c) Close-up details of different rows (L, M and N, O), indicating that the point of impact and the tailing out are reversed for each row. The engraving points also differ from those in Fig. 2, b and c. The top of one mark from the row below is seen at the bottom right in (c), revealing the point of impact and the fact that it is again a reversed row (P).

with a normal wrist action; the bone itself was held in the left hand (*16*). Since there is no change in the design factor resulting from these shifts, the 180° reversals could not be ascribed either to an intent to change the visual pattern or to a desire to achieve a more comfortable grip on the bone or the cutting tool. This was confirmed by the continuing analysis of the broken rows, for the bone had been turned seven times at almost random intervals for the engraving on this face. Sometimes the bone had been turned after each row, sometimes after two, three, or five rows.

To the right and left of this matrix of central, primary sets there are three vertical rows of marks, engraved by points different from those used for the horizontal rows. For the engraving of these rows the bone had been held in various vertical positions, as it had been for the engraving of the horizontal rows. The long row (I) at the left of the central matrix (Fig. 3a) and the row (S) at the bottom right of the central notation (Fig. 4) had been accumulated downward with the bone point up. The marks in Fig. 4 are engraved by three or four different points, each forming a subset engraved at a slightly different angle. For the row (T) at the bottom right the bone had been reversed 180° (see Fig. 10). These rows are apparently "subsidiary" to the central, primary marking and may have been engraved before or after the main sequences. The presence of subsidiary sets before and after the primary notation and engraved by different points has been documented from the beginning of the notational tradition in the Aurignacian and as late as the Mesolithic (*4–7*). It seems to confirm a sequence of marking in which subsidiary periods or sets may initiate a notation and lead to the main body of marks, or act as a terminating period or set. These subsidiary sets are often placed apart from the main marks and are usually less rigidly structured or aligned. In this sense the middle marks on the prior face, the first examined, have the attributes of a subsidiary, perhaps terminating set.

The microscopic data for this broken face, as for comparable Upper

Fig. 4. Detail of the area near the break in mid-bone (see Fig. 1c), indicating the two forehooves of a galloping horse, which were engraved while the bone was held horizontally. Below it is a row of marks engraved by at least three different points while the bone was held vertically. The three marks seen at the bottom left are from horizontal sets in the main notation (R^{3-5}).

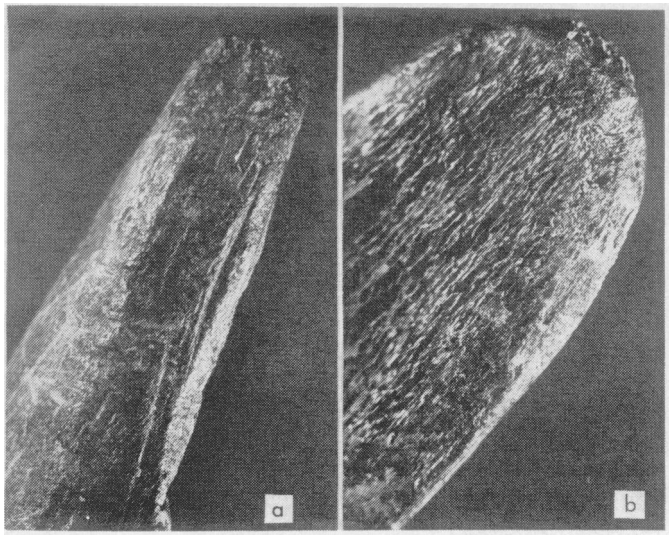

Fig. 5. (a) Detail of the point of the bone fragment, showing the scraping marks that shaped and smoothed the point after the break. (b) The even rounding of the working point, apparently indicating secondary use of the bone as a pressure flaker (see the various angles of this point in Fig. 1, a to c).

Paleolithic and Mesolithic slates, do not suggest random or decorative marking but rather an intentional accumulation of sequential sets divided into subsets and, therefore, of superordinate (although not necessarily arithmetic) "sums." The interlocking data suggest notation.

Since it is not possible to perform tests for possible periodicities with the broken sequences on this face, I turn to the first face examined. Before doing so I present an analysis of the broken edges, since they supply additional validation for the notational intent of the marking on both faces.

The Broken Edges

The jagged horizontal breakage in mid-bone is sharp and undeteriorated, despite a burial of some 15,000 years. The nature of the break suggests that it occurred during a leverage action with pressure applied at both ends, rather than in an accidental smashing or by careful cutting and subsequent excision, which is the usual Upper Paleolithic method of forming bone tools. A leverage break would create the snap in mid-bone, but would also create an exceedingly sharp edge and forward point. Microscopic analysis revealed that the upper edges and surface had been intentionally shaved and smoothed after the break. The strokes of the scraping are still visible (Fig. 5a). The once sharp vertical edges are polished and rounded by the wear of subsequent handling, and the point itself had been intentionally rounded, perhaps by an initial shaving. However, the generalized rounding of the point, with the gradual disappearance of the shaving marks as one approaches the point, suggests that it may have been used as a pressure flaker (Figs. 1, b and c, and 5b). The jagged edge in mid-bone is inset so that it would have offered no problem (*17*).

The break had cut through previously engraved sets, and after this the bone had been modified for a secondary usage. I have described elsewhere (*4, 18*) the use of bone and stone tools and ceremonial objects for notational purposes and the modification of accidentally broken tools to provide a surface for notation.

The Unbroken Face

Examination of the unbroken face indicates that the engraving of sets began near the rounded point and followed the curve of this new shape downward, as though the edge now served as the guide for a second sequence of accumulation. Not one mark among the descending horizontal rows has been cut through by this edge, and the continuing analysis revealed that all the sets on this face were complete. Significantly, the engraved horse on this face and the signs associated with it were also unbroken, whereas all that remained of the horse on the broken face were the head and two front hooves.

Whatever practical usage the bone originally had, it also served as a surface for the engraving of sets of marks associated with an animal. In its second usage it was again a working tool and again served as a surface for the sequential accumulation of sets of marks associated with an animal. The totality and complexity of the marking indicate that it is not a decorative composition. What we have on the La Marche bone,

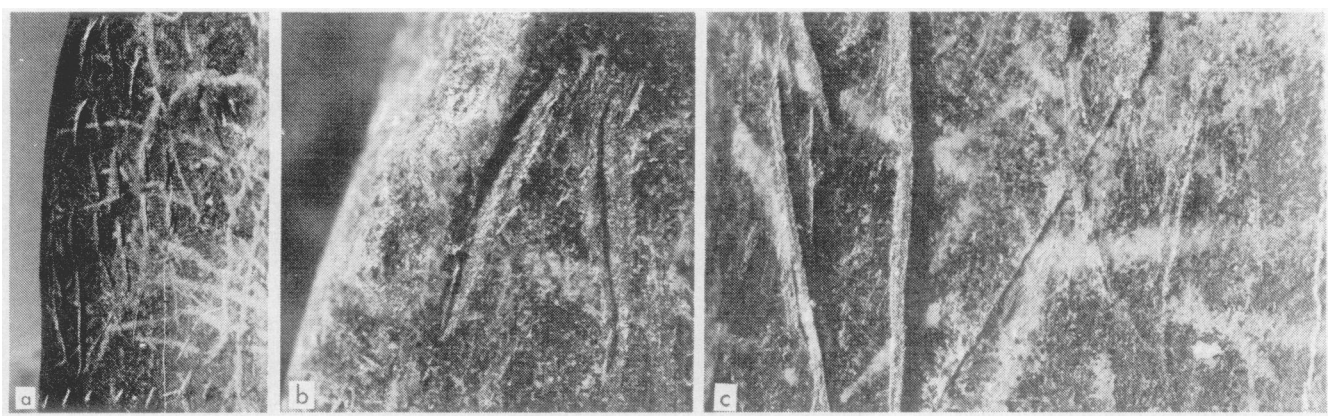

Fig. 6. (a) Detail of the engraved marks near the rounding of the point (Fig. 1a, upper section), indicating the angled marking and the three small rows of vertical marks. At the bottom is the first row of the primary notation. (b) Two marks (A^3) forming an angle with the apex at the top. (c) Close-up to the same scale as (b), showing sections through the deep, sharp marks of the multiple angle of four strokes (C^1), which is crossed over at the right by a lighter angle (C^2). The three angles (A^3, $C^{1,2}$) are engraved by points with different cross sections.

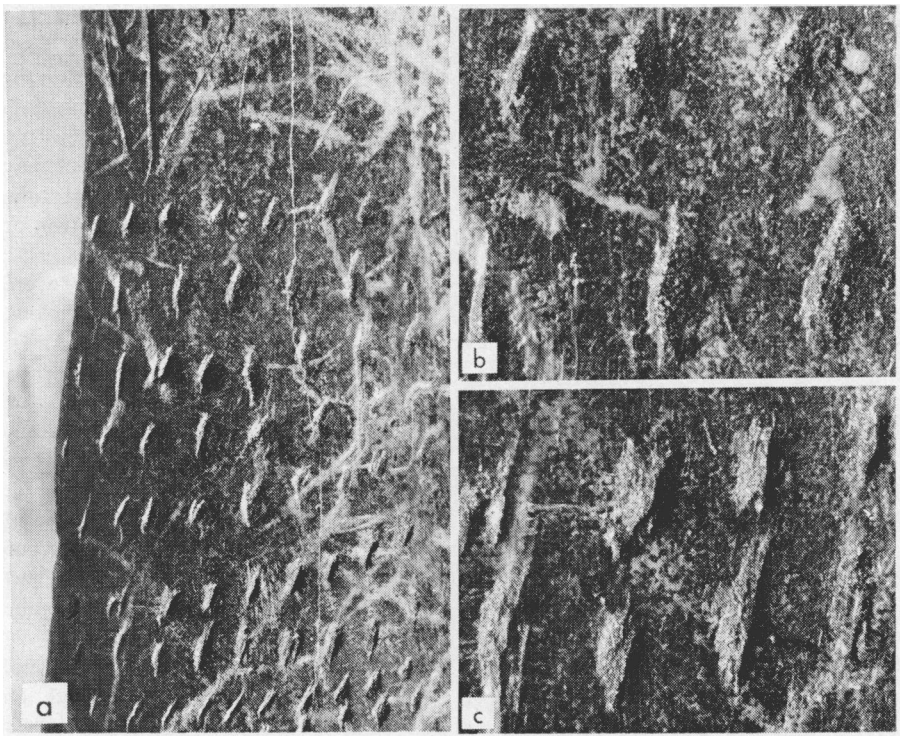

Fig. 7. (a) Detail of the first two sets of the main notation, showing five rows engraved by one point (D^{1-5}) followed by two rows engraved by a second point ($E^{1,2}$). These are followed by the first rows of the third set, engraved by still another point. (b) Close-up of the marks in the first two rows ($D^{1,2}$), indicating the flattened cross section with only one steep wall at the left. (c) Close-up of the marks in the next set ($E^{1,2}$), indicating a different cross section and rhythm of spacing.

then, are two surfaces engraved in different periods, probably by the same hand, certainly in the same cultural context (*19*). The opportunity existed, therefore, for a unique comparative analysis of the separate compositions.

The engraving begins at the top near the arced edge of the rounded point, with the bone held in a vertical position. The opening group consists of three sets of marks (A^{1-4}, B^{1-3}, $C^{1,2}$) engraved in three styles by different points. These become increasingly structured or tight as they descend, and they give the impression of introductory or subsidiary notation (Fig. 6, a to c).

The marks in the first group are angles engraved sparsely, two by two, with the rounded point of the bone held upward. These are followed by three short rows of vertical strokes, engraved after the bone had been turned 180°. Then come two angled forms pointing downward, each engraved by a different point and pressure. The last angle at the right crosses over the larger angle containing four marks, indicating that the direction of accumulation when the bone is held with the point upward is from the edge inward. The last angle terminates the subsidiary or introductory notation (see Fig. 10).

Immediately below, the primary notational matrix begins in the style of the central notations on the other face (Fig. 7, a to c). It begins with five rows (D^{1-5}) engraved by an unusually wide, flat point (✓). The second of these rows begins with a lightly engraved "sign" (Y) which takes the rhythmic place of a regular mark in the series (*20*). Because the cross section of the engraved mark is wide and flat (Fig. 7b), it is not easy in this set to establish the point of impact and the tailing out, but where such a determination can be made the bone seems to have been turned 180°.

The five rows are followed by two rows ($E^{1,2}$) engraved with a different

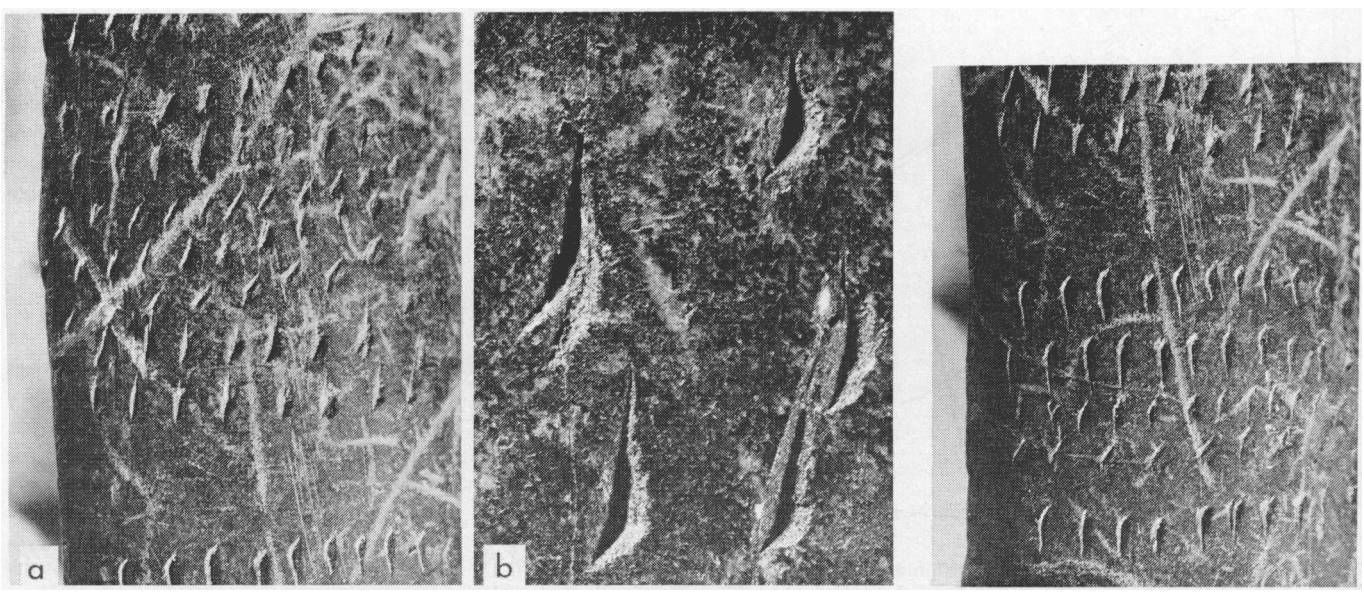

Fig. 8 (left). (a) Detail of the two rows $E^{1,2}$ (top) and the following five rows (F^{1-5}), indicating that the latter set was engraved by a different point and in the reverse direction, upward. (b) Close-up of the last marks in the final two rows of set F ($F^{1,5}$), indicating the point of impact and the upward tailing out. The last mark (bottom right) terminates set F. Fig. 9 (right). Detail of the last two rows of set F and the following five rows of the set below (G^{1-5}), engraved by a different point and in the reverse direction. (For a close-up of the marks in set G see Fig. 2b.)

rhythm and spacing and by a sharper, deeper point (Fig. 7c) having an irregular cross section (⋁). The bone had been held vertically, its point upward, the strokes engraved downward (/).

The next five rows (F^{1-5}) must have been engraved by a different point (⋁) after the bone had been turned 180°, since they tail upward to the right. All the rows in this set were made with a tighter spacing than any above. The third row is made at a different angle and with a shorter, lighter stroke, while the last two rows return to the general angle and spacing of the first two (Fig. 8a). The last mark in set F is engraved higher, at an angle, as though closing out the set (Fig. 8b). These microscopic data for position and rhythm changes within sets suggest that one point or tool may have been used for a period of time because it was the available graver or burin.

The next five rows (G^{1-5}) were made at a considerable distance below, by still a different point (⋁), and after the bone had been turned back 180° (Fig. 9). The third row opens with a light stroke by a different point, and this is followed by two normal strokes forming an angle (Fig. 2c, bottom left). The fourth row in this set was engraved at a different angle, apparently after the bone had been reversed, and the bone was again reversed for the last set.

There is then a large empty space, and we find the middle sequence of three rows (H^{1-3}), which we first analyzed (Fig. 2, a and c), engraved by a different point and style of stroke. This is the terminating set.

The schematic rendition (Fig. 10) indicates that this complex sequence of engraving is neither random nor decorative but is instead notational. Apart from these documented changes in the cross section of the engraving point, note that each set also has its rhythm and angle of marking. The general rhythm of spacing and the downward accumulation on this second face are tighter than on the broken face, which had been engraved when there was a greater available free surface. This tendency to crowd sequences as space lessens during an accumulation, even to overengraving late sets when no free space is left, has been found to be a common aspect of Upper Paleolithic notation (*21*) and is one more indication of a lack of design intent.

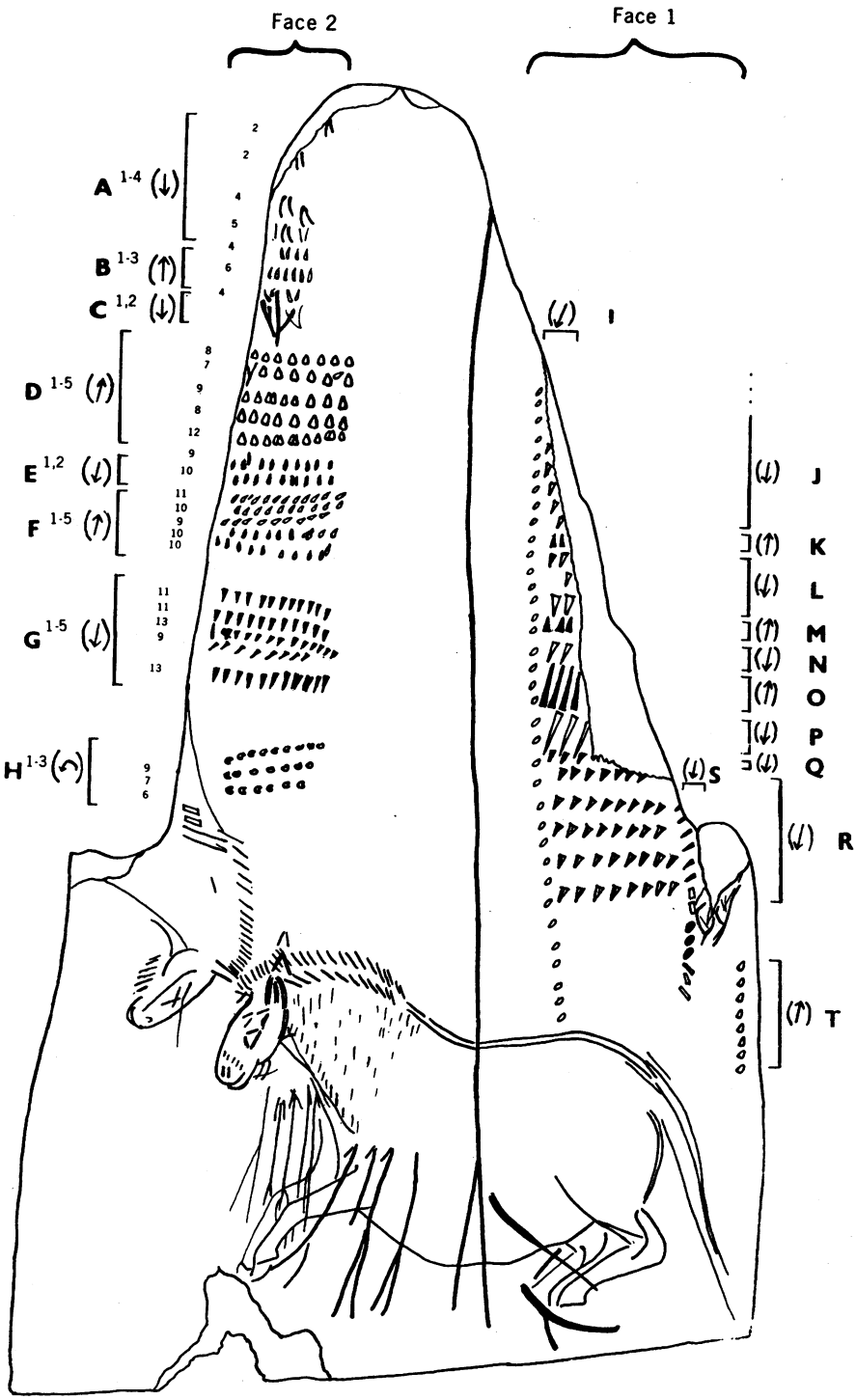

Fig. 10. Schematic rendition of all the intentional marks on the two faces of the La Marche bone, indicating the breakdown into sets, the differences in the engraving points and the direction of engraving, and the sum of marks in each set, as determined by microscopic analysis. Also shown are the two horses with their later additions. The letters near the notations are coded to match the photographs, the text, and the chart (Fig. 16).

The Horses

Microscopic analysis of the horses revealed a comparable complexity of a different order. The unbroken horse, the second one engraved, belongs to the face just analyzed. It is a seemingly pregnant mare with a rounded belly and a delicate muzzle (*22*). Microscopic analysis of the head in profile reveals that it contains three eyes, three ears, and a second mane and back line, made by different points and presumably at different times (Fig. 11, a and

b). The upper mane, the first engraved, crosses over the middle ear, so it is clear that both the lower and upper ears were engraved later. The horse had been reused by the addition of parts of the body (*2, 23*).

In front of, below, and in the horse are darts and "signs." The microscope reveals that these were made in sets of one to four, each set engraved by a different point and pressure and in a slightly different "style." Some of the darts (Fig. 12, a and b) are realistic and contain the point and the feather, others are merely a line with an added stroke indicating the feather, and still others are inverted angles approaching a sign (⟍). The documentation for this tradition of adding animal parts and increasingly abstracted sets of darts has already been published (*2*).

The broken horse of the first face is marked with "sets" of lines (Fig. 13, a and b), which were shown to be darts in an extreme stage of progressive abstraction (*2*).

When comparable renewals, additions, and associations in different styles appear in the painted and engraved caves, it is not possible to determine that they were made either by one culture or in one period. Here is the proof that rather complex compositions may have been accumulated within a relatively limited cultural period, although the additions are clearly in various "styles" of realism and abstraction. These data require a reevaluation of the traditional bases for interpretation of the cave compositions and of attempts to establish chronology on purely stylistic grounds.

The association of animals, weapons, and notation might appear to indicate both hunting magic and killing tallies. The concepts are examined in (*2*) and (*5*) and are found not to conform to the microscopic evidence of repeated renewals and the addition of many classes of signs and symbols, including "nonkilling" signs. Why a complex, cumulative record of animals killed should be kept in differentiated sets over long periods to a final total of hundreds of marks is difficult to imagine and is not confirmed ethnographically. The fact that the engraved animals are not ever fully "killed," since they are renewable, is an indication of image and class constancy such as is found in the ritual killing and sacrifice of the member of a symbolized class rather than in the simplest rituals of hunting magic, where the image is made, killed, and ceases. Of greater relevance, the research has revealed that (i) the animals in compositions with depicted killing or renewal do not represent generalized game or the generic species, but are often seasonally, sexually, and maturationally differentiated, and (ii) the notational sequences in the Magdalenian are associated with insects, plants, frogs, feathers, fish, seal, stags in the velvet stage, bison in the moulting stage, and even female anthropomorphic figures (*4, 5*). In sum, the "killings" seem more applicable to periodic ritual or sacrifice at specialized times than to random acts of magic intended for success in the hunt for food.

A terminal, evolved Magdalenian example in the style of the La Marche bone clarifies the tradition. In Fig. 14, a and b, I present a line rendition,

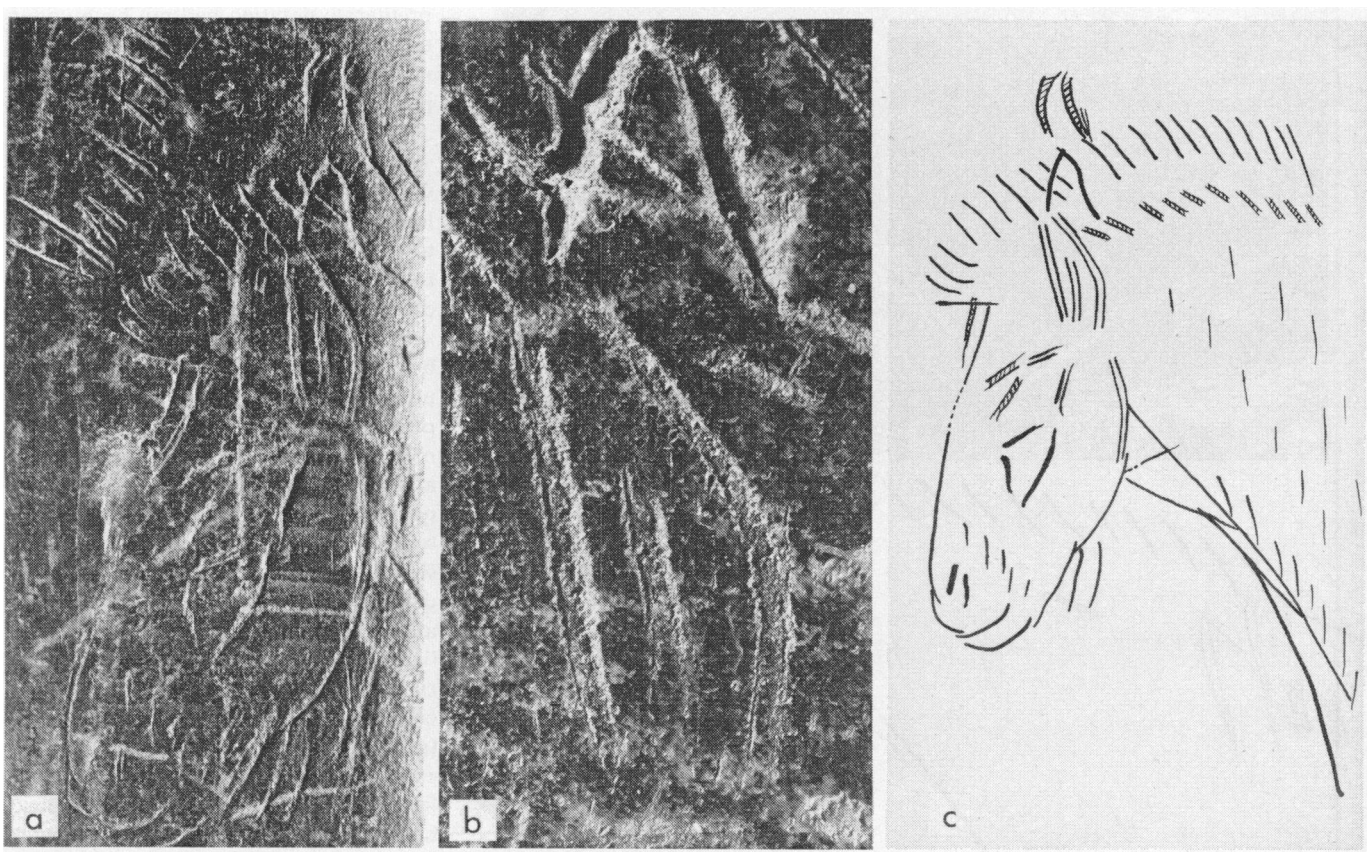

Fig. 11. (a) Detail of the head of the second horse, showing the three ears (engraved by different points), the three eyes (engraved by different points), and the beginning marks of the second lower mane. The marks at the upper left are from the mane of the first, horizontal horse. (b) Close-up of the first ear, above, and the lower ear, indicating the differences in the engraving points and the fact that the engraved marks of the mane cross over the first ear. Two marks from the later, lower mane are at the right of the second ear; they were engraved by a different point from that used for the mane above. (c) Schematic rendition of the head, showing the ears, eyes, and manes.

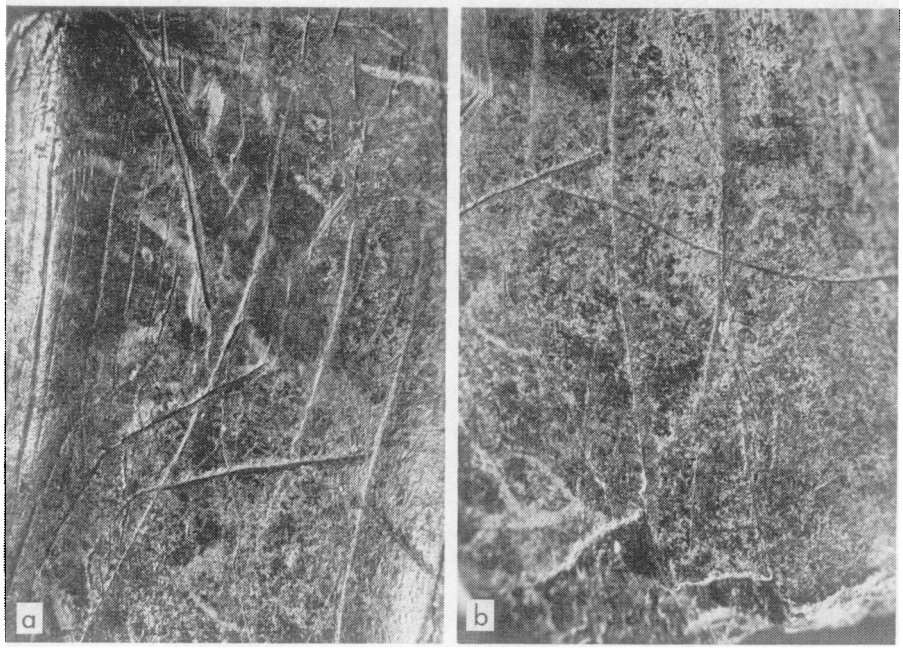

Fig. 12. (a) Detail of the forelegs of the second horse, indicating the feathered, pointed darts in front and the long lines of another set of darts, engraved by a different point, crossing into the body. (b) Detail of the bottom of two long darts entering the belly of the horse, showing the two feathers, each made by a single added stroke at an angle.

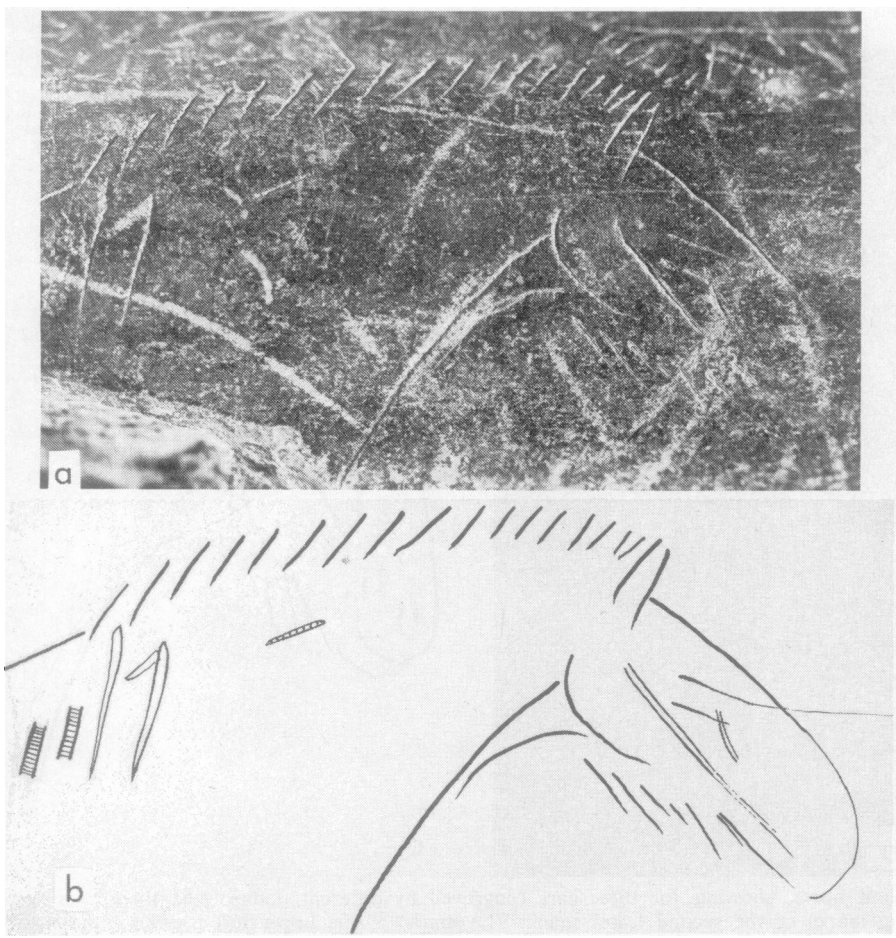

Fig. 13. (a) Detail of the head of the first horse indicating the doubled eye and added lines in the neck. (b) Schematic rendition of the head showing the intentional additions to the eye and the five neck marks made by three different points.

based on microscopic analysis, of the two faces of a broken baton from Cueto de la Mina in the Asturias region of northern Spain (Magdalenian VI, c. 10,000 B.C.) (*24*). Sets of unit marks are accumulated downward, each differentiated by engraving point, angle of making, style of stroke, rhythm, and placement. Opposite each set is the image that supplies part of its meaning (Fig. 15): two ibexes, the first of which is crossed over, and four plant images, each representing either a different species or a stage of growth (*25*).

The combined evidence documents a cognitive process in which diverse images, various acts of participation (darts, renewals, crossing over), and notations are associated and accumulated. The images suggest a range of possible meanings, but it is clearly in the ubiquitous notations that the clue to the tradition lies. I turn, therefore, to the problem of interpretation.

Notational Analysis

A systematic study of prehistoric, preliterate notation had not been undertaken before the present research, to my knowledge, and so the theoretical problems have never been discussed. The effort was not necessary if the sets were considered as hunting tallies. One early attempt was made by Absolon (*26*) to impute a decimal system to the presumed hunting tallies. A microscopic analysis of his published examples revealed no such counting system. Later Frolov (*27*), influenced by my early research, suggested the use of the number seven and its multiples in the engraved Upper Paleolithic materials on the basis of the mythical and mystical significance of the lunar quarter. Analysis of the European materials outside of the Soviet Union shows no special use of that number despite an apparent lunar observation and notation (*4, 5*). These authors relied on ethnographic comparisons rather than on intensive, methodological analysis of the artifacts. The cognitive complexity of the La Marche example and of others recently published (*5, 6*) indicates the impracticability of making simple ethnographic comparisons across a span of 12,000 years and more. The accumulating analytic data suggest that during the Upper Paleolithic there were a number of notational systems in use of which

the La Marche example is one. Painted sets in the caves of the period apparently represent a different meaning. Their analysis is being prepared (*28*).

The analytic problems in the study of prehistoric notation differ substantially from those solved in studies of the history of science, writing, arithmetic, geometry, and astronomy. The latter involved analyses of rigidly formal, internally structured systems of symbols. The Upper Paleolithic notations represent an informal tradition whose basic system is the accumulation of sets and subsets, but the precise form or style of the accumulation was not culturally determined except in general terms. It was open to wide individual variation. Our data are therefore not only those of the symbol system but equally those of the analytic methodology; they are microscopic, sequential, and cognitive. Only after the primary analyses do the data become "numerical." But this numerical breakdown of sets, as in Fig. 10, is the result of modern analysis; the sets need not have been recognized or utilized numerically by the maker. We cannot assume that the counts of 11, 12, and 13, for example, were numerically defined, or that the 221 marks which appear on face 2 represent a recognized or utilized sum. There may have existed an ability to count, but the breakdown of sets and subsets provides no evidence for it.

The microscopic evidence for sets and subsets can also be misleading. The documentation reveals that the eight sets A to H were engraved by different points, indicating an accumulation in time. These microscopically determined eight sets need not have been eight culturally or cognitively significant sets for the maker. Cross-sectional differences were not a visual element for the engraver. The microscope merely documents that one tool, a burin or graver, was kept and used over a period which included the making of a set and its subsets. Regarding these changes, it is significant that the last mark in a set never reveals breakage; the point of impact, the cross section, and the tailing out are the same for all the marks in the final subset. This is added evidence that the new tool was taken up not because of breakage but because it was the tool of a different time.

The only tests that can be conducted with a preliterate notation consisting of sets of unit marks when the supporting linguistic or semantic structures are not available are those intended to determine if the sets are random or indicate arithmetic or calendric periodicity. If the notation were mnemonic or narrative, no regularity or periodicity would be found. Early tests revealed no system of counting in the tradition, so a methodology was devised to test long sequences of sets of unit marks for possible lunar periodicities within a system of non-arithmetical notation and observation (*4*, *5*).

In testing the La Marche notation, there is no reason to suppose that the period of use of a graver or burin should match the lunar month. It would sometimes last longer, sometimes less. The light, fine engraving of marks would cause no great wear or change in the point. The total length of all the marks in a set is but a few centimeters. In contrast, any engraving on stone or heavy engraving on bone or antler can cause a point to deteriorate. If the typically small burin were carried in a pouch with the bone as the tool for occasional fine marking it might last for weeks. In such a case the varying shapes, sizes, and engraving points of the burins would be elements in determining the rhythm and stroking in a set. The chances are that for the same purpose the most comfortable and effective grip would be used repeatedly with the same small tool.

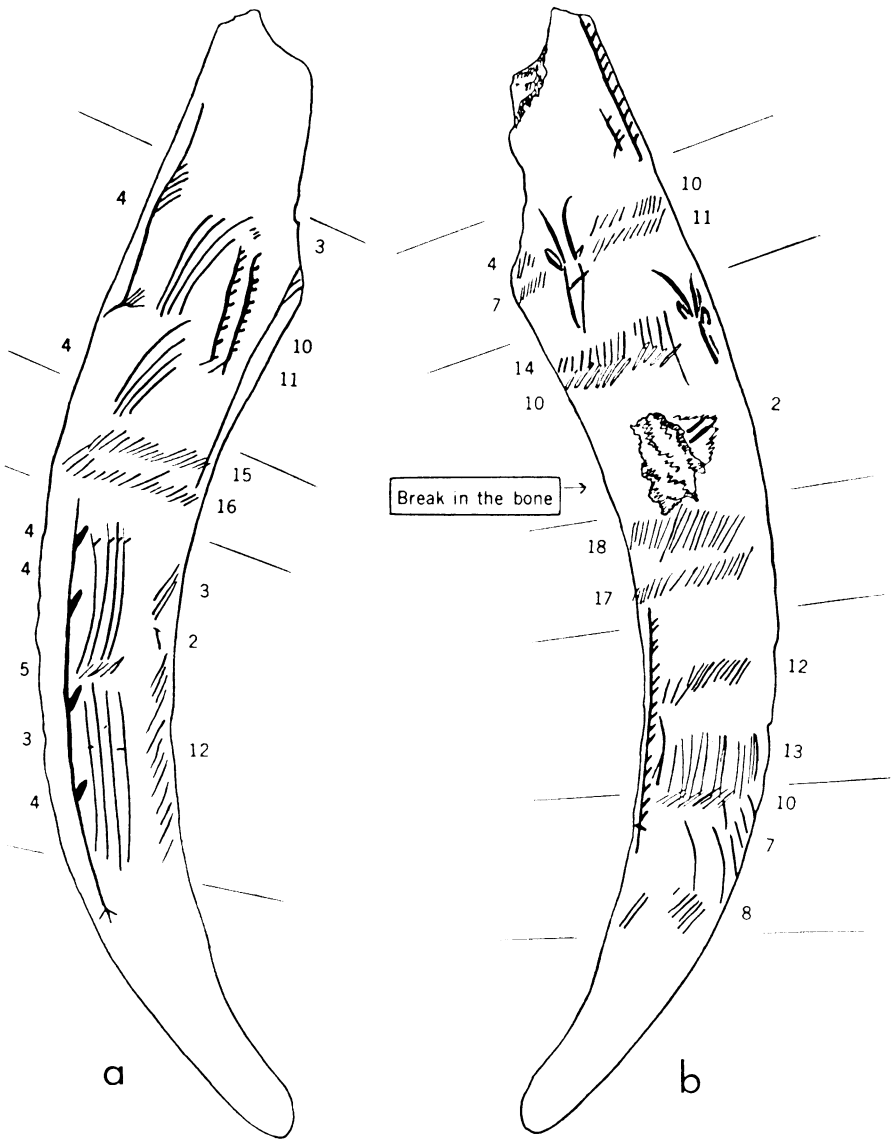

Fig. 14. Schematic rendition of all the intentional marks on the broken baton from Cueto de la Mina, Asturias region, Spain, indicating the sets and subsets on each face and the associated images of plants and ibexes. The accumulations are from the top downward. One set (b) in mid-face lacks an associated image.

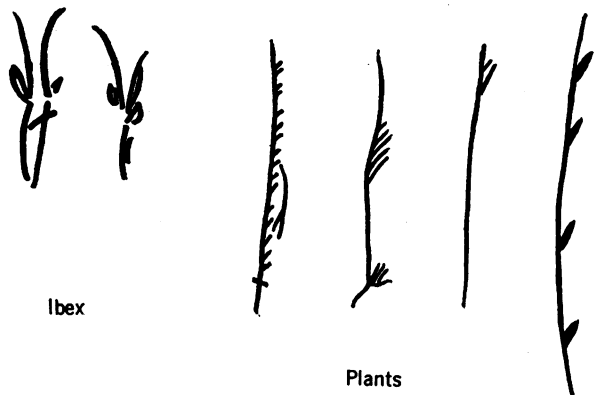

Fig. 15. The engraved images on the baton from Cueto de la Mina. There are four plant images of different species or stages of growth and two ibexes, the larger struck through by a single mark. One plant has an added sign.

We cannot, then, assume that the sets as determined by the microscope mark off a lunar month. There should, however, be a lunar phrasing among the subsets since an engraving tool would be taken in hand to begin a subset. The Upper Paleolithic tradition consists of a marking by subsets and almost never, apparently, are the marks made or accumulated one at a time. Whether this implies an ability to count will be discussed in another paper (*29*).

The microscopic data also document a persistent, although random, turning of the bone. Despite this, the accumulation was always downward from the rounded point, at least for the main notation. In such a system it makes no difference to the maker if the added set is engraved with the bone held in one direction or the other; the accumulation proceeds properly and the "reading" is maintained.

The analytic data, then, differ in many respects from those available to and utilized by the engraver. His differentiations were by cultural and visual, kinesthetic and cognitive recognitions and recalls of a different type, including his knowledge of the sequence of making and his decisions concerning placement. Since every notation is by definition the abstraction of other semantic systems, it is the known sequence, structure, and periodicity of these other systems that make the notation possible and practicable. I assume then, without evidence, that the La Marche sequence was given meaning by such corollary semantic systems, which were linguistically, culturally, and traditionally maintained. One of these may have been an early system of counting or enumeration.

Lunar Test

When the sequence of sets and subsets on the second face of the La Marche bone is laid against a lunar model (Fig. 16) beginning with the days of the dying moon and last crescent, the full sequence of subsets that follow give an almost perfect observational notational phrasing. The subsets begin or end properly at observational phase points, within the limitations that we would expect today in an observational lunar notation kept in the European mid-latitudes. In the sequence of 23 subsets, only four (E^2, F^2, $G^{1,2}$) do not begin or end at normal phase points. Of these, three include the observationally difficult period of the crescents and the new moon within the subset, with a crescent 1 or 2 days from its precise astronomical occurrence, and one (G^2) begins a day earlier than the true quarter. This is a remarkably close tally for an observational lunar notation. Scrambling these subsets randomly provides sequences without persistent lunar matching. Lunar tallies comparable to the La Marche occur in other Upper Paleolithic notations (*4*, *5*).

The totality of marks covers 7½ months. The introductory subsidiary notation begins with the approaching last crescent of one month and ends at the last crescent of the next. This month of introductory notation is

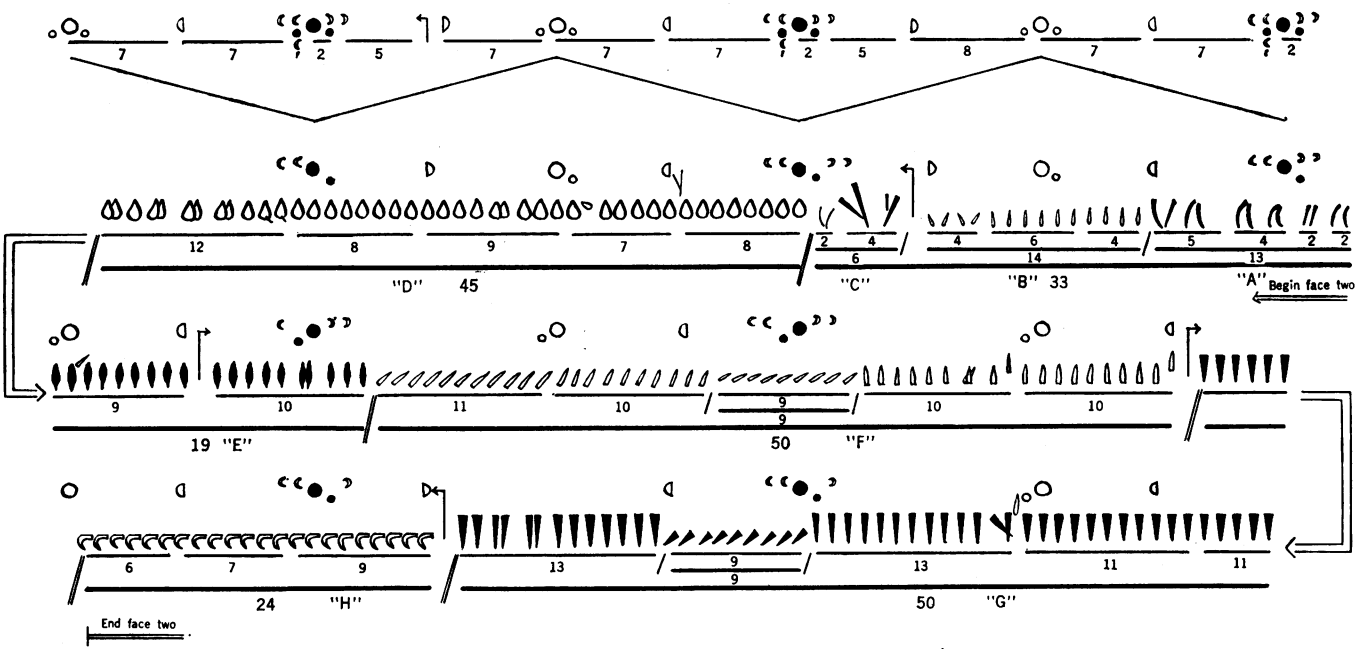

Fig. 16. Test of the La Marche notation on the first face against a lunar model. The chart begins at the upper right and proceeds sequentially in alternate directions along each line, ending at the bottom left. One space in each 2 months (the right-angle arrow) represents zero, providing the proper total of 59 marks for 2 months in a model scaled to 60. The lettered sets, subsets, and cue marks and the astronomically correct observation point are indicated. The differences in the engraving points are schematically rendered.

followed by 5¾ lunar months of primary notation. The subsidiary terminal set (H^{1-3}) begins at last quarter with the dying moon and ends at the full of the following month, which would then represent, observationally, an additional "moon" or month marked or signified by the full.

The test indicates with a high degree of probability that the notation is lunar. Why, however, should a hunter-gatherer maintain a lunar notation which is not arithmetically structured or precise and which does not visually and symbolically mark off set months?

Notational Month

A tradition of lunar notation that is maintained by the necessary corollary recognitions and systems provides for each month its own phenomenological markers. If the first angle in Fig. 16 is engraved after the first 2 days of thaw, when the winter recognizably breaks, then the month A-B-C would be the "moon of the flood." At any point in the sequence of accumulation that then follows the engraver would know the name and processes of the month whose passage he is marking, as well as the sequence of those already notated and those to come. Here the ethnographic data are of assistance.

The regional and linguistic groups of historic North American Indians represented different peoples and stages of economic development and specialization ranging from pure hunting and gathering to farming. Despite wide, basic cultural differences they almost all maintained in one form or another a lunar "calendar" (*30, 31*). Unfortunately, the ethnographic data, while voluminous, were often poorly collected, coming primarily from informants who happened to be available and were willing to talk. What was usually obtained was the traditional sequence of month names, a kind of folklore reference. These Indian month names always represented the seasonal sequence of regional phenomena, economic activities, or ceremonies. Among groups where months were numbered there were the usual descriptive names as well. This sort of naming sequence existed in historic times among the Yakut and other Siberian peoples (*9, 10*).

The Upper Paleolithic notations, particularly when they are as complex as those on the La Marche bone, suggest that they were kept by some specialized person. Cope, writing of the American Indian, states (*30*, p. 130): ". . . the more complex and highly developed the ceremonialism . . . the more careful the determination of the solstices, the lunar phases and the time reckoning." Indian informants were almost never those whose specialized task it was to keep the economic and ceremonial sequence. While the American Indian records were seldom on bone and stone, usually being kept on wood and skins, rare calendric notations have survived and, like the Yakutian examples, these lend meaning to the Upper Paleolithic notations (*11, 32*).

If we assume, for explanation, that the 7½ months of the La Marche notation began with the thaw late in March and that the first, subsidiary month was therefore April in our calendar, the notation would have ended in mid-November with the first frost or snow. Such a sequence need not have been numbered or marked off as set months, but could be maintained by the Siberian-American Indian naming tradition (*33*) and other corollary semantic systems.

The compositions by Upper Paleolithic artists which illustrate or imply seasonal and other periodic ceremonies and rites (*5*) suggest that at least some were "scheduled" in the year as in the Siberian and American traditions. The difference is that the Upper Paleolithic provides a rich, continuous documentation in notation. If we now assume three or four ceremonial or ritual "killings"—real, danced, engraved, or painted—together with renewals involving the horse as a central character in the myth or rite, then the complete engraving on the La Marche bone provides an internal consistency and lends a new level of meaning to a corpus of Upper Paleolithic art and notation.

Beginning of Writing

By definition, writing is a notational system that has been formalized so that it can be used and read by the maker and by anyone else familiar with the formal tradition. The cultural and economic pressures for such a stable, interpersonal system are greater where there is farming and village life. They do not exist at the same level for the hunting group.

The cognitive strategies in the Upper Paleolithic notations differ, therefore, from those found in writing, where the regularities of an aligned surface, a culturally assigned direction of accumulation, a finite library of signs, and a specialized body of equations of relevance are essential for the rereading. The open variability of the Upper Paleolithic notations suggests that they were used by the engraver alone, although explanation of the tradition and of any notation and its associated images would have been possible. The process would entail cognitive, linguistic, and abstractional complexities comparable to those involved in writing and far greater than those previously theorized for the period.

A tradition in which widely understood, phenomenologically related signs and sets and subsets connected with lunar periodicities were accumulated had a great potential for developing into pictographic writing and, eventually, arithmetic (*34*). Current research has made a beginning in documenting the development toward such a prewriting accumulation of symbols and an apparent arithmetization of sets and subsets in the late Magdalenian and the cultures that followed.

References and Notes

1. More than 1000 whole and fragmented mobiliary artifacts have been examined microscopically and documented by photomacrography in 80 private and institutional collections in nine European countries, 1965 to 1972.
2. A. Marshack, *Riv. Sci. Preist.* **24**, 219 (1969).
3. ———, *Anthropologie Paris* **74**, 321 (1970).
4. ———, *Notation dans les Gravures du Paléolithique Supérieur*, F. Bordes, Ed. (Institut de Préhistoire, Université de Bordeaux, Bordeaux, France, 1970).
5. ———, *The Roots of Civilization* (McGraw-Hill, New York, 1972).
6. ———, *Curr. Anthropol.* **13**, 445 (1972).
7. ———, in *Actes du Symposium International d'Art Préhistorique*, E. Anati, Ed. (Centro Camuno di Studi Preistorici, Capo di Ponte, Val Camonica, Italy, 1970), pp. 479–494.
8. The use of signs or images in association with sets of unit marks is well documented in calendrics and record-keeping; the English clog almanac, the Scandinavian rune stick, and the European peasant and Gallo-Roman peg calendars are well known. Less well known but cognitively comparable examples occur in Asia, Africa, and the Americas [see P. Marti, *Objets Mondes* **4**, 29 (1964); E. P. Orlova (*9*); L. Delaby (*10*); and R. H. Merrill (*11*)].
9. E. P. Orlova, in *Sibirskii Arkheologicheskii Sbornik*, T. M. Nazaryantz, Ed. (Novosibirsk, U.S.S.R., 1966), pp. 297–321.
10. L. Delaby, *Objets Mondes* **8**, 311 (1968).
11. R. H. Merrill, *Bull. Cranbrook Inst. Sci.* **24**, 6 (1945).
12. The microscopic documentation in this article was presented without interpretation in an explanation of methodology at the 8th Congrès International des Sciences Préhistoriques et Protohistoriques, Belgrade, September 1971, and at the annual meeting of the Society for American Archaeology, Bal Harbour, Florida, May 1972.
13. P. Graziosi, *Riv. Sci. Preist.* **1**, 215 (1946); S. Lwoff, *Bull. Soc. Préhist. Fr.* **38**, 145 (1941), **54**, 620 (1957), **59**, 73 (1962), **61**, 271 (1964); L. Pales and M. Tassin de Saint Péreuse, *Les Gravures de la Marche*, F. Bordes, Ed. (Institut de Préhistoire, Université de Bordeaux, Bordeaux, France, 1969); in *Miscelánea en Homenaje al Abate Henri Breuil* (Instituto de Prehistoria y Arqueología, Diputación Provincial de Barcelona, Barcelona, Spain, 1965), vol. 2, pp. 217–250; *Objets Mondes* **4**, 77 (1964), **7**, 307 (1967); in *La*

Préhistoire, Problèmes et Tendances (Éditions du Centre National de la Recherche Scientifique, Paris, France, 1968), pp. 327–336; L. Pericard and S. Lwoff, *Bull. Soc. Préhist. Fr.* **37**, 155 (1940); L. Pradel, *Mém. Soc. Préhist. Fr.* **5**, 170 (1958).
14. S. Lwoff, *Bull. Soc. Préhist. Fr.* **39**, 51 (1942), figure 3.
15. The bone was examined in 1967, 1968, and 1970, each time after work with other engraved materials had revealed additional aspects of the symbolic engraving tradition. The results of the first analyses appear in (*5*). In this article I correct that version with the microscopic data concerning the use and reuse of the La Marche bone.
16. There is considerable microscopic documentation for basic right-handedness in the engraving of the extremely fine Upper Paleolithic compositions and notations, the left hand having served as the retainer and aligner. The evidence for an alternation in the direction of engraving and, at times, of reading images and notations is one of the unexpected findings of the microscopic method and is among the clues that have made possible the sequential analysis of complex compositions (*2–6*).
17. Two traditional Aurignacian "plaques," reinterpreted by microscopy as pressure flakers used for fine retouch and also engraved with cumulative notations on both faces, are analyzed in (*4*) and (*5*).
18. A. Marshack, in *Prehistoric and Roman Studies*, G. de G. Sieveking, Ed. (Trustees of the British Museum, London, England, 1970), pp. 137–145.
19. Two eagle bones from a single site and level (Le Placard, Charentes, France, Magdalenian IV) each engraved with notations in the same style and perhaps by the same hand, have offered the only other evidence for rigidly contemporaneous comparison (*4, 5*).
20. The use of signs and cue marks with notations is common in the historical period (*8–11*) and has been extensively documented for the Upper Paleolithic in (*4*) and (*5*).
21. See (*4*), figure 2, p. 10 and figure 27, p. 43, and (*5*), figure 24, p. 93.
22. The differentiation of stallion, mare, and colt in a single composition by nonsexual dimorphic characteristics is documented in (*5*), chapter 11. The depiction of seasonal, sexual, and age differences is common and is documented for many species in (*3*) and (*5*).
23. The Upper Paleolithic tradition of reusing or renewing an animal image by the addition of parts of the animal, documented for the mobiliary materials in (*2*), has been verified by microscopy for the cave images by M. Lorblanchet. In a memoir now in press (M. Lorblanchet, preprint) he documents the addition of engraved eyes, ears, and manes and also the addition of muzzles, legs, and other parts as described in (*2*).
24. R. Vega del Sella, *El Paleolítico de la Cueto de la Mina* (Comisión de Investigaciones paleontológicas y Prehistóricas, Madrid, Spain, 1916), plate XXXIX: 2, a and b, and plate XL.
25. An abstract of the analysis of this example appears in (*5*), pp. 213–218, and its cognitive contents in (*6*). A complete documentation is in preparation.
26. K. Absolon, *Artibus Asiae* **20**, 123 (1957).
27. B. Frolov, in *Actes du Symposium International d'Art Préhistorique*, E. Anati, Ed. (Centro Camuno di Studi Preistorici, Capo di Ponte, Val Camonica, Italy, 1970), pp. 475–478.
28. The National Science Foundation is presently supporting the development of spectroscopic techniques for analysis of the painted cave compositions.
29. A. Marshack, in *Proceedings of the Symposium on Mesoamerican Archeology*, Cambridge, England, 1972, in press.
30. L. Cope, *Univ. Calif. Publ. Amer. Archaeol. Ethnogr.* **16**, 119 (1919). Cope documents the widespread tradition of lunar and seasonal naming sequences for the North American Indian, which is comparable to the Siberian tradition documented in Orlova (*9*) and Delaby (*10*). See also L. Spier (*31*).
31. L. Spier, *Bull. Mus. N. Ariz.* **28**, 16 (1955).
32. W. R. Goldschmidt, *Amer. Anthropol.* **42**, 176 (1940).
33. A model based on images from Upper Paleolithic compositions with notations that have been published (*4, 5*) might be: Moon of the Thaw (April); Moon of the Spring Salmon Run (May); Moon of the Calving (June); Moon of the Flowers (July); Moon of the Moulting (August); Moon of the Rutting Bison (September); Moon of the Nut (October); Moon of the First Frost (November).
34. See (*5*), figure 101b, p. 213.
35. The research was funded by the National Science Foundation and the Wenner-Gren Foundation. Special thanks to H. L. Movius, Jr., curator of Old World Archaeology, Harvard University, who supported and supervised the research and helped make the development of the methodologies possible.

Mössbauer Spectroscopy: Recent Developments

The current status of Mössbauer spectroscopy is reviewed, emphasizing materials science applications.

R. L. Cohen

The Mössbauer effect (*1*), more formally known as "recoil-free gamma-ray resonance absorption," was first reported in 1958, and was, just 2 years later, the subject of a topical conference. Experimental research with the use of the Mössbauer effect has diffused so rapidly into the diverse fields of solid-state physics, metallurgy, chemistry, and biochemistry that it has become impossible to follow as a united field. One participant leaving the 1964 conference on the Mössbauer effect remarked that "this was not simply the Third International Conference on the Mössbauer effect, but the *last* such conference." This prophecy has turned out to be correct—although many conferences have been held since that time in which research involving the use of Mössbauer spectroscopy has been the main subject (*2, 3*), there has been no attempt to reunite all workers using the technique. Approximately 15 research papers involving the Mössbauer effect are published each week, and it is virtually impossible to keep up with the literature of the entire field.

Why has the technique become so popular? What kind of research is being done? What are the future possibilities? In this review I will concentrate (after a brief introduction) on two basic points. First, I discuss a few recent results which exemplify the way in which "traditional" techniques of Mössbauer spectroscopy have provided useful information for those who are not Mössbauer spectroscopists. In keeping with the current enthusiasm for the application of pure research techniques to "relevant" problems, I emphasize the recent uses of Mössbauer spectroscopy to study problems apart from its uses in the determination of hyperfine structure and isomer shift (these terms are defined below). "Applications" of Mössbauer spectroscopy have usually consisted of analytical determinations, in which the spectrum of the sample is compared with that of standard materials, but I would like to use a somewhat broader definition here. Included in the sections on applications are a number of efforts in which the significant result has been qualitative information on the *existence* of multiple lattice sites, or information on a valence change of the ion being studied. This sort of result can be applied to biological and materials science problems in a much more direct way than the usual investigation of isomer shift and hyperfine structure (hfs), and gives people unfamiliar with the tech-

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